Extreme Event Modeling

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

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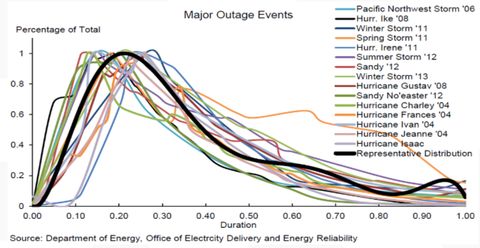
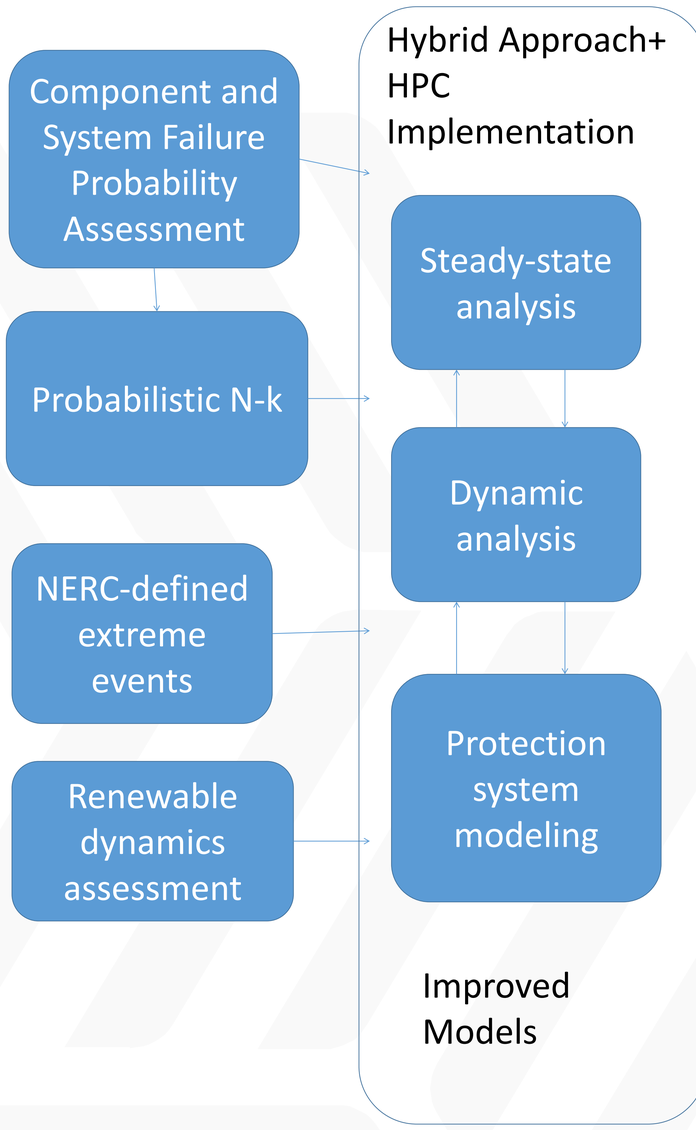
Project Description

Extreme events pose an enormous threat to the nation's electric grid and the socio-economic systems that depend on reliable delivery of power.

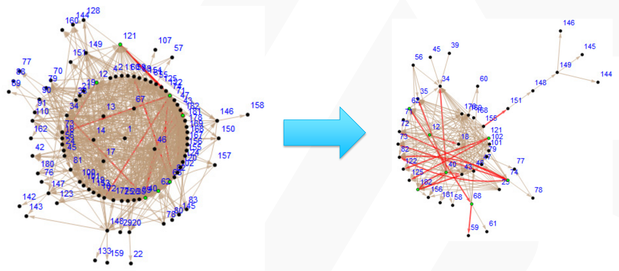
- Superstorm Sandy, Hurricane Katrina, the 2003 Northeast blackout
- Component Failure (N-k) and Sequential Component Failure (Cascade) modeling has large gaps
  - Cascade models having missing details
    - Low fidelity
    - Reliability regulations difficult to satisfy
      Example: NERC TPL-001-4
  - Simulations of cascades are slow
    - Impractical for real-time planning exercises
  - Component failures (N-k contingency analysis)
    - Existing approaches address a small number of failures (k < 4)
    - Existing approaches assume all failures are equally likely



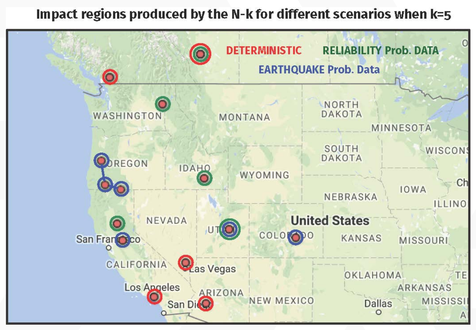
Source: Department of Energy, Office of Electricity Delivery and Energy Reliability



Cascade simulation speed ups



Contingency Analysis with Probabilities



Expected Outcomes

- A prototype set of tools for efficient cascade modeling and probabilistic N-k identification.
- Tools that are 500x faster than existing industry cascade simulation packages
- Identify the worst (probabilistic) k contingencies where k is twice as big as existing practices

Significant Milestones	Date
Implementation of Zone 3 Protection in Cascade Models	1/1/17
Survey of Past Outages and Extreme Events	1/1/17
Extreme Event Research and Development Strategy Document	4/1/17
Cascade modeling tools demonstrate 10x of cascade simulations as compared to existing tools	10/1/17
Scale N-k approaches to networks that are 10x larger than existing tools can handle	10/1/17
Cascade modeling tools demonstrate 100x of cascade simulations as compared to existing tools	10/1/18
Open source prototype tools release that 1) Integrates multiple temporal scales, protection system modeling, and renewables into cascade models, 2) demonstrates 500x speedup of cascade simulations as compared to existing tools, and 3) improves computation of N-k by increasing k by twice as much over existing practices.	4/1/19

Progress to Date

- Extreme event modeling strategy document
  - Gaps in extreme modeling, directions for addressing gaps
- Industry Webinars
  - June 16, 2016, Jan. 25, 2017
  - FERC, Caiso, Idaho Power, MISO, PLM, DOM, SPP, NERC, DVP
- Publications
  - X. Zhang, Y. Xue, Y. Liu, J. Chai, L. Zhu, and Y. Liu, *Measurement-based System Dynamic Reduction Using Transfer Function Models*, submitted to 2017 North American Power Symposium (NAPS)
  - Q. Huang, B. Vyakaranam, R. Diao, Y. Makarov, N. Samaan, M. Vallem, and E. Pajuelo, *Modeling Zone-3 Protection with Generic Relay Models for Dynamic Contingency Analysis*, PES General Meeting, 2017
  - Wenyun Ju, Kai Sun, and Junjian Qi, *Multi-Layer Interaction Graph for Analysis and Mitigation of Cascading Outages*, IEEE Journal on Emerging and Selected Topics in Circuits and Systems, under review